TRUE GEOTHERMAL ENERGY COMPANY

HAWAII OFFICE
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Honolulu, Hawaii 96813
Telephone: 528-3496

895 WEST RIVER CROSS ROAD

Phone (307) 237-9301
P.O. Box 2360
Casper, Wyoming
82602

November 15, 1989

HAND DELIVER

Mr. Paul Aki
Chief, Air Quality Branch
Department of Health
State of Hawaii
Restaurant Row Building
Attn: Wilfred Nagamine

Subject: Hydrogen Sulfide Chemical Abatement Treatment Plan.

Dear Mr. Aki:

Enclosed is a copy of the above described plan required pursuant to special condition #18 of the Authority to Construct (No. A-815-768) issued to True Geothermal Energy Company on September 20, 1989.

The plan follows industry practice and procedure in its preparation and format. Should you have any questions in regard to the plan, please do not hesitate to call me at 528-3496.

Very truly yours,

TRUE GEOTHERMAL ENERGY COMPANY

Allan G. Kawada

Encl.

cc: Manabu Tagomori, DLNR (with Encl.)

AGK/ea

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

H2S ABATEMENT PLAN

TRUE/MID-PACIFIC A1-1
COUNTY OF HAWAII

NOVEMBER 1989

ThermaSource Inc.
P.O. Box 1236 • Santa Rosa, CA 95402

H2S ABATEMENT PLAN
TRUE/MID-PACIFIC A1-1

I. Purpose

This Plan is submitted pursuant to ATC No. A-815, special condition 18.

The Plan covers abatement procedures that will be employed during the drilling testing of True/Mid-Pacific Geothermal Well A1-1 and subsequent wells. Operations will be employed to treat and maintain H2S emissions below 8.5 lbs/hr in compliance with the ATC.

II. Description of Abatement Operation

Abatement practices presented in this plan have been adopted from existing plans commonly utilized in The Geysers Geothermal Field in California. SPE Paper 7882 is the primary reference for the abatement theory.

A. Chemicals

Caustic (sodium hydroxide, NaOH) will be used to treat the H2S produced from the geothermal well because caustic has a high affinity for hydrogen sulfide. Brewer Chemical Company has been contacted, and they have provided assurance that caustic is available on the Big Island in the necessary quantities. Brewer has a bulk terminal in Hilo with approximately 100,000 gallons of storage capacity. Brewer will deliver caustic to the drill site in a 50% solution in 3500 gallon tanker trucks.

In addition to caustic, hydrogen peroxide is sometimes used to convert the sodium sulfide into sodium sulfate. Hydrogen peroxide does not react directly with H2S, rather it tranforms the treated compound to a more stable form. Peroxide will not be used unless it becomes necessary. Brewer Chemical will also supply the peroxide if it is needed.

B. Caustic Storage

On-site:

Working tank:	3600 gallons (provided by Brewer)
Backup tank:	1800 gallons (with injection pumps)

	5400 gallons

Off-site:
Tanker truck: 3600
====
Total: 9000 gallons

C. Applications

1. Aerated Drilling

In liquid dominated geothermal areas, drilling the resource bearing formations with an aerated fluid is becoming more important. The two major advantages over drilling with mud are:

prevention of formation damage
and
faster penetration rates.

While drilling with an underbalanced system such as air, geothermal fluids along with non-condensible gases enter the wellbore and are produced at the surface. Thus the need to monitor and maintain emissions below regulated levels. If emissions of H2S exceed 8.5 lbs/hr, then caustic must be injected into the flow stream to remove the H2S from the steam. Because of the presence of the drill string (5-1/2" diameter) in the wellbore (8-1/2" diameter), production of geothermal fluids is restricted to a large degree.

When the drill string is out of the well to change bits or drilling assemblies, the well could have the potential to produce considerably more geothermal fluids and hence H2S. It is also possible that the well will die because the temperature and pressure of the reservoir are not sufficient to sustain flow. The injection rate of caustic is then adjusted for either condition.

The third condition that requires H2S abatement with caustic is during well testing. Production rates will tend to be higher than during drilling and more stable.

III. Abatement Equipment

A. During Drilling

Figure 1 is a schematic of the system that will be employed during the drilling phase. Air or aerated water is pumped down the drill string and exits on bottom. The drilling fluids mix with the formation cuttings and produced

fluid, and all are returned to the surface. This mixture flows out into the blooie line and then to a cyclone muffler. The blooie line is about 50' long and is 12" in diameter. Caustic is injected at the earliest point possible in order to maximize chemical reaction time.

Precision metering pumps are used for the injection of caustic from the storage tanks to the blooie line. Twin pumps are available for redundancy and also for emergencies when a high injection rate is needed. Two additional pumps are available for backup as well as for injecting hydrogen peroxide should that become necessary. Peak pumping capacity for a single pump is 120 gals/hr. This will theoretically abate 162 lbs/hr of H2S at 4:1 mole ratio.

The equipment setup and injection scheme is essentially unchanged for testing. During well testing, a 10" diameter line will be used but otherwise the piping system and sampling points are the same.

IV. Implementation

A. Checkout

All equipment and abatement personnel will be prepared to implement this program when air drilling begins approximately 45 days after spud-in. Prior to this time, all equipment will be checked and calibrated. Exlog/Smith will be the abatement contractor on this well. They have a great deal of experience in H2S abatement on geothermal wells. They will have personnel on-site 24 hours a day during drilling of the well.

Brewer will be notified to fill all caustic storage tanks prior to commencement of air drilling. Thus there will be 5400 gallons available at the inception of air drilling.

B. Measurement and Abatement Procedure

Figure 2 is a block diagram that depicts the H2S Abatement Procedure that will be followed. A continuous H2S monitor will provide direct H2S measurements in the blooie line upstream of the chemical injection point. Although such measurements have not always been reliable, they do provide a qualitative representation of H2S levels. Due to the relative uncertainty of the direct measurements, wet chemical tests (silver nitrate titration) are relied on for regulatory purposes. The procedure is a straightforward

one and an example determination sheet is shown in Figure 3.

Since H2S emissions are the product of H2S concentration and the steam flow rate, it must be determined by some means. Because there are no known direct methods of measuring steam in a two-phase system, simple but accurate approximations are used.

(1) Steam Flow Rate While Drilling

The steam flow rate while drilling, in pounds per hour, will be determined by measuring the ratio of condensate to non-condensable gas flowing from the well. A full wellstream sample of steam and air produced during drilling is withdrawn from the blooie line. The steam is condensed and weighed and the volume of the corresponding non-condensable gas is measured in a volume chamber. The measured ratio of the amount of condensate, i.e., condensed steam, to all non-condensables, primarily air from the compressors, is equal to the ratio of the total steam flow to the amount of air injection. The steam flow rate is found by multiplying the measured ratio by the rate of air injection (equation 1).

Eqn 1:

$$SFR = \frac{C}{NC} \times AIR$$

Where:

SFR = steam flow rate(lbs/hr)
C = weight of condensate(grams)
NC = weight of non-condensable gas(grams)
AIR = air injection rate(lbs/hr) (measured at the air compressors with orifice meters)

The above equation is based on a material balance and assumes (1) all the air injected into the well is reproduced, and (2) the non-condensable component of natural steam flow is insignificant when compared with the air injection rate.

(2) Steam Flow Rate While Out-of-Hole

Two methods are available. The first method of determining out-of-hole steam flow rate involves making a correction to the drilling steam flow rate. During drilling, steam flow up the well bore is restricted by the drill pipe. For abatement purposes, it will be assumed that the restriction is equal to the ratio of drill pipe cross section area to well bore cross section area. The correction factor is found using equation 2.

Eqn 2:

$$C = \frac{A(dp)}{A(wb)}$$

Where: C = correction factor
A(dp) = cross sectional area of drillpipe
A(wb) = cross sectional area of well bore

The correction factor is used to find the tripping steam flow rate by its application in equation 3.

Eqn 3:

$$OSFR = \frac{SFR}{1-C}$$

Where: OSFR = out-of-hole steam flow rate
SFR = drilling steam flow rate (from Eqn 1)
C = correction factor (from Eqn 2)

A second method can be used if the brine flow rate is known. The level in the sump can be monitored and its rise correlated to brine flow. Then, using a combination of energy balance and mass balance equations, an approximate flow rate can be determined. Figure 4 shows the Flow Factor that can be multiplied by the brine flow to get steam flow.

Once the H2S concentration and steam flow rate are known, the emission rate can be calculated. Caustic must be injected at the appropriate rate to reduce emissions below 8.5 lbs/hr.

Because the exact composition of the geothermal steam is unknown, a trial and error process must be used to determine the optimum caustic injection rate. Initial chemical treatment ratio will be 4 moles of caustic per mole H2S. This is equivalent to injecting 0.739 gals/hr of caustic for each pound of H2S to be abated. Abatement efficiency will be monitored by performing a wet chemical test on a steam sample as it exits the top of the drilling muffler. Chemical injection rate can then be adjusted based on the test results.

The first wet chemical test will be conducted when the first steam or hot water entry is encountered. Additional wet chemical tests will be conducted daily and after each significant resource entry.

V. Permanent Records

A permanent log book will be kept at the well location during drilling operations into which the following entries will be made at least four times daily and reported daily to a Department of Health Office by 12 o'clock noon each business day.

A. H2S concentration in parts per million (ppm) by weight prior to treatment with abatement chemicals.

B. H2S emissions in pounds per hour upstream and downstream of the chemical treatment point.

C. Injection rates of NaOH.

D. Volume of chemicals on location.

E. Daily, zero and span checks of H2S sensor.

Additional entries will be made when significant changes in steam flow occur and/or changes are made in injection rates of NaOH.

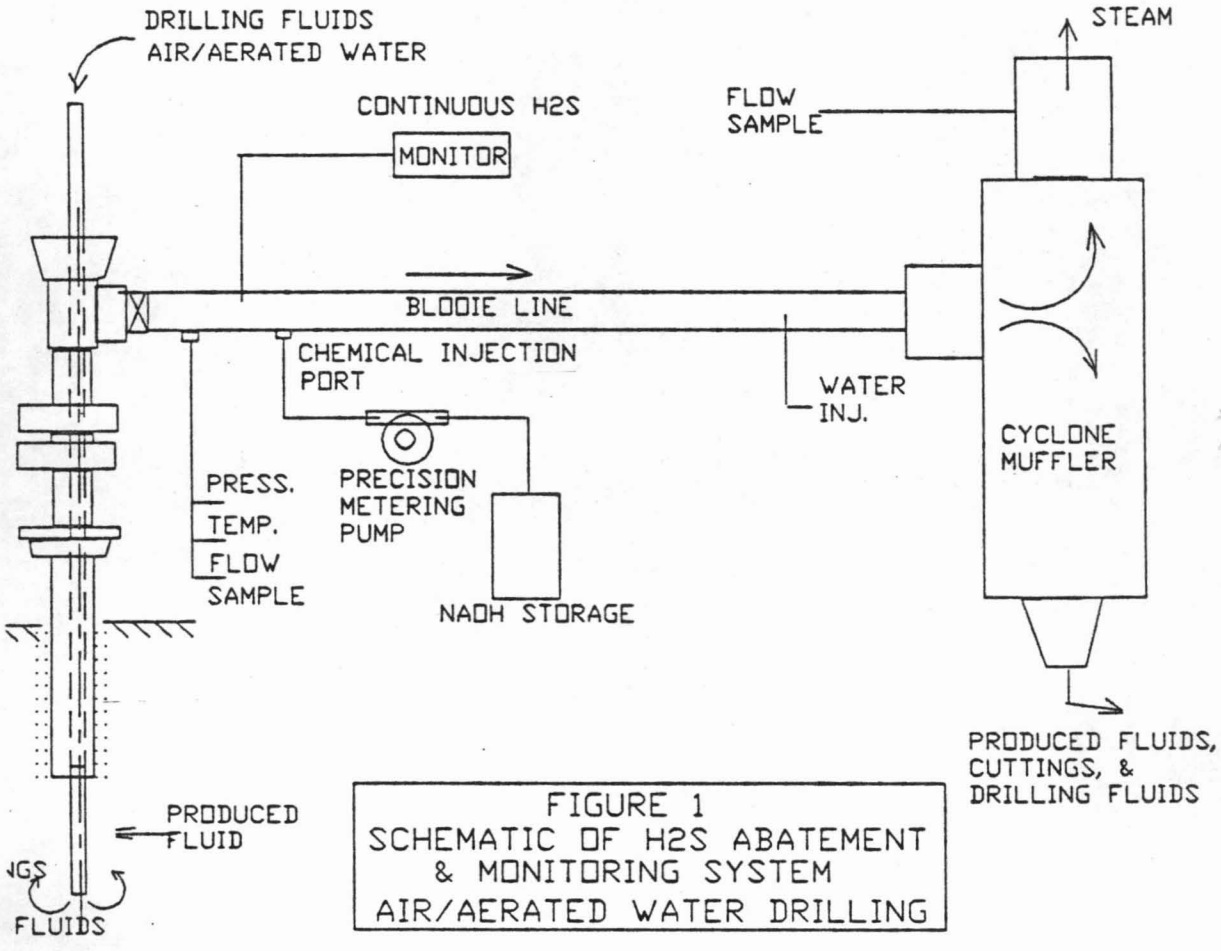

FIGURE 1
SCHEMATIC OF H2S ABATEMENT
& MONITORING SYSTEM
AIR/AERATED WATER DRILLING

FIGURE 2

H2S ABATEMENT PROCEDURE

TRUE/MID-PACIFIC A1-1

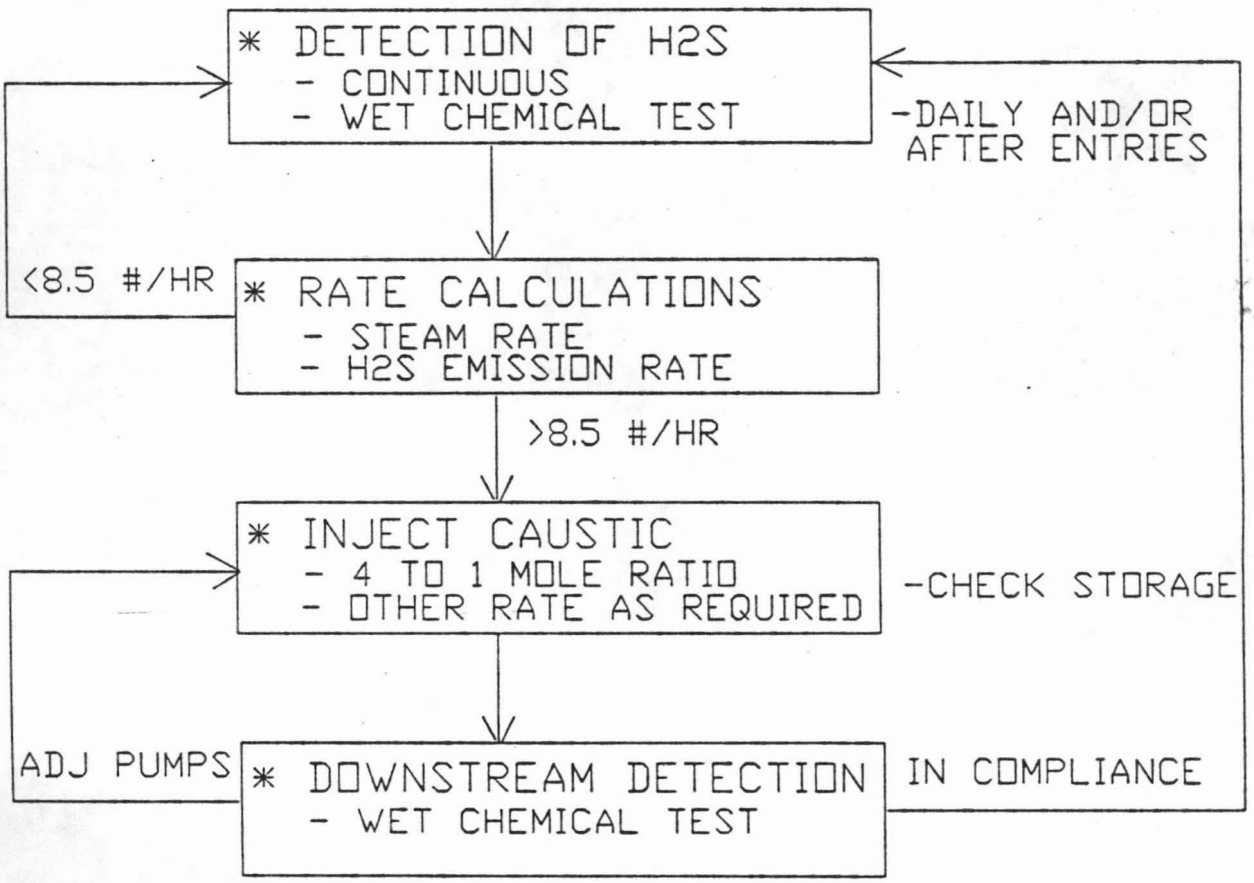

FIGURE 3

EXLOG SMITH GEOTHERMAL DIVISION

R.F. Smith Corporation

P.O. Box 666
Cobb, California
95426

Telephone: 707-928-5772

HYDROGEN SULFIDE DETERMINATION

OPERATOR _____ FLOW RATE _____

Well NO. _____ ORIFICE SIZE _____

DATE/TIME _____ WELL PRESSURE _____

TECHNICIAN _____ WELL TEMPERATURE _____

REMARKS _____

I. SAMPLING

(A) Weight of gas wash bottle _____

(B) Weight of bottle + NH_4OH _____

(C) Weight of bottle, NH_4OH + sample taken _____

II. TITRATION

	Sample #1	Sample #2	Sample #3
Weight of beaker + sample			
Weight of beaker			
Weight of sample			
Final buret reading			
Initial buret reading			
Total $AgNO_3$ used			

III. POTENTIAL READINGS

Sample #1		Sample #2		Sample #3	
Buret Reading	Potential	Buret Reading	Potential	Buret Reading	Potential

DATA FOR H_2S DETERMINATION

CALCULATIONS:

$$H_2S\ (ppm_w) = \frac{\text{ml. } AgNO_3 \quad \frac{10^{-3} \text{ g. } H_2S}{1 \text{ ml. } AgNO_3} \quad \frac{\text{Grams of Codensate + } NH_4OH}{\text{Grams of Condensate}} \quad \frac{10^6\ ppm_w}{1}}{\text{Grams of Titrated Sample}}$$

$$H_2S\ (ppm_w) = \frac{(\text{Volume } AgNO_3 \quad (10^3) \quad \frac{(C-A)}{(C-B)}}{\text{Weight of Sample Titrated}}$$

SAMPLE #1 H_2S = _____ = _____ (ppm_w)

SAMPLE #2 H_2S = _____ = _____ (ppm_w)

SAMPLE #3 H_2S = _____ = _____ (ppm_w)

Average H_2S = _____ (ppm_w)

CALCULATION FOR STEAM FLOW BY CONDENSABLE/NON-CONDENSABLE RATIO:

$S = \frac{C}{N} \times A$

$S = \left(\frac{\quad}{\quad}\right) \times (\quad)$

$S =$ _____ (#/hr)

S = Steam Flow (#/hr)

C = Condensate (gms)

N = Non-Condensable (l) X 1.1 $(\frac{g}{l})$

A = Air (CFM) X 4.17 $(\frac{\#/hr}{CFM})$

FIGURE 4

STEAM FLOW RATE ESTIMATION

SURFACE CONDITIONS:

atmospheric		hs =	1149
T = 208F		hw =	176

BOTTOMHOLE CONDITIONJS

BHT (F)	Psat (psia)	Hsat (BTU/lb)	Adj Hsat (BTU/lb)	Flow Factor
300	67.0	270.0	243.0	0.07
350	134.5	322.0	289.8	0.13
400	247.0	375.0	337.5	0.20
450	422.5	430.0	387.0	0.28
500	681.0	488.0	439.2	0.37
550	1044.0	549.0	494.1	0.49
600	1543.0	617.0	555.3	0.64
650	2209.0	696.0	626.4	0.86

Steam Flow = Flow Factor x Brine Flow

JOHN WAIHEE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

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RICHARD H. COX
GUY K. FUJIMURA

MANABU TAGOMORI
DEPUTY

REF:WL-BM

OCT 24 1989

Mr. Hank A. True III
True Geothermal Energy Company
P.O. Box 2360
Casper, Wyoming 82602

Dear Mr. True:

Pursuant to the Department of Land and Natural Resources' Conservation District Use Permit identified as CDUA HA-12/20/85-1830, and the Board of Land and Natural Resources' Decision and Order, dated April 11, 1986, an air quality monitoring program for the permitted geothermal exploratory activities shall be implemented when the well drilling period begins and shall continue through the term of the project.

The air quality monitoring program shall be conducted by an independent consultant selected by the Department, and shall be paid for by the permittee (True/Mid-Pacific Geothermal Venture).

As such, the Department has evaluated the qualifications of the firm of Measurement Technologies of San Louis Obispo, and has designated said firm as the authorized independent consultant for the required air quality monitoring program.

Please implement the necessary arrangements to hire Measurement Technologies, including the scheduling of the start of the air quality monitoring in coordination with the initiation of your drilling program.

Should you have any questions, please contact Manabu Tagomori, Deputy Director, at (808) 548-7533.

Very truly yours,

William W. Paty